JOURNAL OF BIOELECTRICITY, 9(1), 33-54 (1990)

ENHANCEMENT OF TEMPORAL LOBE-RELATED EXPERIENCES DURING BRIEF EXPOSURES TO MILLIGAUSS INTENSITY EXTREMELY LOW FREQUENCY MAGNETIC FIELDS

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ABSTRACT

Volunteers wore opaque goggles while sitting quietly within an acoustic chamber that was weakly illuminated by a red light. During six successive 5-minute periods each subject received 3 pairs (off/on) of either 4 Hz, 9 Hz or 16 Hz, 0.3 mG to 1.0 mG (100 nT), pulsed magnetic fields (both polarities) that were applied externally at the level of the temporal lobes; a fourth group received the sham field. Subjects exposed to the magnetic fields displayed enhanced vestibular, depersonalization and imagining experiences compared to sham-field controls. Pleasantness scores were positively correlated with numbers of temporal lobe spikes; both measures were enhanced within the field conditions. When variance associated with psychometric inferences of temporal lobe sensitivity and cognitive style was accommodated, a significant increase in temporal (but not occipital) lobe alpha activity for the groups exposed to the magnetic fields was revealed. These results suggest that weak, pulsed magnetic fields, focused across the temporal plane, may generate neurostructure-specific behaviors within a context that encourages their occurrence.

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INTRODUCTION

We (1-3) have been interested in the psychological experiences and the phenomenological details that are correlated with normal neuroelectrical activity within the mesiobasal region of the human temporal lobes. The hippocampus and the amygdala are two of the most important structures of this region. They are involved with accessing declarative memory (the conscious or active recall of not only what was learned but when and where it was acquired) and with attributing personal meaning or significance to the constant stream of sensory input.

These areas are also the most electrically labile portions of the human brain. This property, a necessary correlate of the neurochemical mechanism by which memory is consolidated, is most evident in the brains of people who display limbic or temporal lobe epilepsy. People with this enhanced electrical lability often display quantitative increases in the report of mystical or paranormal experiences, altered states, an inordinate interest in poetry or philosophical (religious) themes, hypergraphia, a sense of a special purpose and a widened effect whereby infrequent or unusual events (such as transient astronomical or social phenomena) acquire special, personal meaning (4,5).

Electrical stimulation of the hippocampal-amygdaloid complex of these people within surgical settings is well known to evoke specific and vivid phenomenological themes (6-8). They include intense dream-like imagery, depersonalization (out-of-body-like experiences), a sense of intense meaning, apprehension (or fear) and the experience of vibrations or tingling sensations. The specific type of experience is roughly correlated with the locus of stimulation. For example, olfactory experiences are evoked most commonly within the rostral temporal poles while gustatory sensations are evoked more frequently when the parietal-insular region is recruited.

However, limbic epilepsy is only the extreme condition of the temporal lobe activity continuum along which all human brains are distributed. Persinger and Makarec (9-11) and Neppe (12) have shown systematic relationships in normal people between the numbers of temporal lobe signs or symptoms and the quantitative incidence of paranormal/mystical experiences, enhanced imaginings (especially from childhood), widening affect, vestibular (floating, low frequency vibration) sensations, anomalous smells, and intense episodes of personal meaning (usually between 2:00 and 4:00 in the morning). These subjective reports are also positively correlated with an increased range in electroencephalographic activity in the temporal but not the occipital lobes (11).

Normal people with enhanced numbers of possible temporal lobe symptoms, but with no documented medical history of epilepsy, display more extremes along the dimension of hypomania and depression (9,13). They show behavioral predilections that are similar but less intense than those associated with focal electroencephalographic discharges. During periods of duress normal individuals who display temporal lobe signs exhibit elevated anxiety (about loss of the self) and more stereotyped, forced or delusional (often suspicious) thinking. During hypomanic episodes, often paired with productive periods, these individuals are more impulsive, intuitive and immensely creative (14). It is not surprising that poets, actors,

actresses and writers dominate the nonpathological, upper end of the continuum of temporal lobe sensitivity.

During the last decade Persinger and his colleagues (9,15-19) have been investigating procedures by which the functional organization of the normal human temporal lobe could be inferred. They have been particularly interested in the specific temporal lobe activity pattern that accompanies anomalous subjective experiences that range from mystical episodes to near-death phenomena (20,21). This domain has been selected because of its superficial similarity to the correlates of limbic electrical seizures that are precipitated by catastrophic biochemical events such as local ischemia or corticosteroid surges. Following these events there is substantial cognitive restructuring, altered beliefs and behavioral modifications that often last a life-time.

These researchers have assumed that specific neuroelectrical patterns within deep temporal lobe structures are associated with specific phenomenological themes. Although the details of any stream of subjective activity would be dominated by the individual's reinforcement history, the general theme should be structure specific. The hypothesis demands a more subtle and intricate equivalent of the concept that the focus of electrical activity in a limbic epileptic patient can be inferred by careful examination of the antecedent subjective experience (e.g., smell, visual sensations, auditory experience). Similar concepts have been developed in psychiatry (22) and cognitive neurology (23).

In order to evoke, noninvasively, specific neuroelectrical patterns within the temporal lobes, weak extremely low frequency magnetic fields have been generated across the temporal plane of the brain; one pole is applied over the left hemisphere while the other is applied over the right hemisphere. Vivid experiences, often very personally significant to the experient, have been generated (24,25). The major themes have involved vestibular sensations (floating, spinning, vibration, out-of-body experiences), a sense of a presence, relaxation and volleys of vivid images.

Our approach is not to coercively induce currents within the brain but to redirect or alter the pathways of operational neuronal ensembles by applying very small amounts of energy in strategically appropriate patterns. We have decided to use weak (less than 100 milligauss) magnetic fields with temporal characteristics that are similar to those generated by the human amygdala and hippocampus. The idea emerged when partial amnesia to complex narratives was noted during exposure to an irregular signal that was generated by an eccentrically constructed commercial device (the Relaxit) when it was applied over the temporal skull (26,27); sine-wave and square wave patterns, of comparable intensity, produced by a function generator were not effective.

This perspective can be expressed metaphorically in the following manner. If one wanted to induce cognitive changes in a person through the use of a 1000-Hz sine wave sound signal, then substantial amounts of energy would be required. The primary cognitive response would be simple and crude: avoidance of the area. However, much less energy would be required to evoke behavioral changes if the sonic wave was presented in a pattern that was relevant to the person. For example, the complex wave whose temporal structure carries the equivalent of "you have just been promoted" would generate much greater and personally relevant cognitive sequelae.

To facilitate the occurrence of time-varying, magnetic field-evoked images, the subject sits in a comfortable chair. Because auditory evoked potentials from random ambient noise are easily produced within the temporal lobes and would interfere with the control of ongoing phenomenological processes, the chair is located within an acoustic chamber; it effectively eliminates all spurious noises. After the use of several different protocols, we found that the total removal of extraneous visual input from the chamber (by producing an opaque visual field) encouraged the necessary internal orientation. In order to compare these results to correlative studies that are examining the response of nocturnal melatonin level to magnetic field applications, the chamber is illuminated by a dim (photographic developing) red light.

Three major factors predict both the intensity and occurrence of these experiences. The first factor involves the demand characteristics of the situation. Instructions and their accompanying innuendos can guide the general theme of experiences. Consequently if a frame is set that involves space themes, the experiences are often involved with a sense of alien presence (24); some mundane variant of a close encounter experience is reported. If the set (simply by the presence of one or two religious artifacts on a wall and the incidental background of context-appropriate music) involves more philosophical contexts, then the experiences are dominated by events of personal significance; reflections about death are not unusual in this context.

The second major factor is the cognitive style and personality of the person. Although the actual phenomenological themes are dominated by temporal lobe functions, their elaboration and attribution are clearly coupled to the psychological characteristics of the person. People who display frequent temporal lobe signs generate more frequent and intense experiences. People who emerge further along the feeling, perceiving and (sometimes) intuitive dimensions of the Myers-Briggs Type Indicator (MBTI) generate more elaborate experiences in a variety of settings (28). Interestingly, the more personal beliefs are compartmentalized from cognitive knowledge, a combination that is disproportionately over-represented in students who major in the physical sciences, the more likely the person attributes the experiences to ego-alien sources, i.e., originating from outside the person or caused by the setting.

Simple calculations, remarkably comparable to the empirical data from neurosurgical studies, indicate that experiential phenomena are evoked when: (1) steep electrical gradients with volumes in the order of 1 cc (3) are induced in deep temporal lobe tissue; and (2) the temporal structure of the induced electric field is resonant with the endogenous, statistically dominant discharge pattern of the region. These criteria are difficult to achieve when the currents are induced by applied magnetic fields because they disperse quickly as they exit their poles of origin. Consequently the field gradient is quite homogeneous by the time it reaches the depths that are considered important. Focusing should occur, even with these fields, if a small area in either temporal lobe contained tissue with anisotropic conduction properties; this could be encountered within a subclinical electrical focus due to either an ontogenetic or an acquired anomaly.

In more recent studies (25) we have attempted to circumvent this problem by utilizing the spatial derivative. The external, time-varying

magnetic field source is also rotated within a circular pattern through pairs of solenoids that are distributed over the surface of scalp at the level of the temporal lobes; the most convenient method (although it ignores individual differences in cranial volume) has been to embed the solenoids into a modified motorcycle helmet. Induction of brief vortices as the field appears and disappears over an area in conjunction with the actual temporal structure of the field is more effective.

In this paper, we present the results of the application of pulsed magnetic fields of different frequencies over a fixed region of the temporal lobes. If our hypothesis is correct, then the appropriate field pattern can potentially alter the normal discharge pattern of neuronal ensembles within deep limbic structures. Because this area is also prone to the phenomenon of kindling, whereby repeated (30 seconds) electrical stimulations directly (by electrodes) within the tissue over several days can result in paroxysmal activity, a conservative exposure protocol was designed. A volunteer received only a single session.

Although both theoretical and clinical reviews indicated that risks of serious sequelae were minimal, any procedure that might evoke changes in the cognitive structure of a human being must be seriously considered. Because many subjects considered their experiences personally significant, we concluded that the potential clinical usefulness of this procedure warranted further elaboration.

METHOD

Subjects

A total of 36 male and female undergraduate university students volunteered to be subjects; there were 18 males and 18 females; ages ranged from 18 to 25 years. The subjects were assigned to one of four treatment conditions: 9 Hz, sham field, 4 Hz, and 16 Hz, in a continuous serial order. Volunteers whose questionnaire data suggested a history of epileptic seizures were excluded from the study.

Apparatus

The magnetic fields were generated through two solenoids between which the subject's head was placed; each solenoid consisted of a nail wrapped with 1040 turns of 22 gauge wire. The solenoids were maintained within a modified set of headphones. Square wave signals (Heath-Schlumberger Function Generator, Model EU-81A) were modified by passage through the filter circuit (0.1 μF). The solenoid and the filter forced an oscillator circuit; the resulting ringing effect was caused by the amplitude-decreasing sine wave (resonant frequency determined by an inductor (5.91 mH) and resistor (5.2 Ω) that was triggered by the rising and falling edge of the square wave source. This resulted in a modified spike or impulse. The rise time of each spike was less than 0.1 msec; the exponential decrease returned to zero polarity within 0.3 msec, proceeded through a maximum reversed polarity at 0.6 msec and then returned to the zero condition at 1.0 msec. The amplitude of the maximum reversed polarity was one-sixth of the initial rise peak. A positive and negative mirror

occurred at the beginning and the end of each wave. This meant that a 4-Hz square wave, passed through the circuit, generated 4 initially positive and 4 initially negative pulses per second.

All of the field generating and monitoring equipment was maintained outside of the acoustic chamber that served as the exposure area. A power-frequency field meter (Model 113-2) indicated magnetic field levels (with larger values occurring nearest the solenoids and the smallest value occurring within the region in which the central portion of the subject's brain would be exposed): 0.3-0.4 mG for 4 Hz, 0.4-0.6 mG for 9 Hz and 0.8-1.0 mG for 16 Hz. A small solenoid, mounted near the magnetic field source allowed verification of its presence when the apparatus was activated during the protocol. The background magnetic field strength within the 1 Hz to 1 kHz range, within the acoustic chamber (and around the chair in which the subject sat), was 0.025 mG or 2.5 nT; this value was homogeneous in the vertical and longitudinal dimensions, but a factor of 4 higher in the horizontal dimension. The heterogeneity was related to chamber wiring.

Procedure

Each subject had been given the Personal Philosophy Inventory (9) and the Myers-Briggs Type Indicator four to six weeks before the exposure day. On that day (December, 1988 through June, 1989, primarily between 1400 and 2100 hr LT) each subject was brought into the laboratory and asked to sit in a comfortable armchair that was housed within an acoustic chamber; it was opaque to AM radiofrequencies, as determined by the absence of local reception (or static) by transistor radios. The subjects were told that the experiment was involved with relaxation; they were instructed to report all of their experiences, even if they might appear strange, and that their identities would remain confidential.

Silver disc electrodes were then attached by EC2 electrode cream above the temporal (T3/T4) and occipital (O1/O2) lobes; an arrangement for heart rate was also established. Goggles, constructed of the two halves of a ping-pong ball, each lined with cotton to enhance comfort, were placed over the eyes. The two solenoids were then placed parallel to the temporal plane (so that the magnetic field passed through the brain) above the posterior temporal lobe (approximately T5/T6). To minimize neck muscle artifacts, the subject was requested to rest the back of his/her head on the chair. After the lapel microphone had been activated, a red (photographic developing) light, placed 1 m in front of the subject, was switched on. The experimenter activated the Astral Sounds Tape (10, San Francisco, CA), left the chamber and closed the door. The tape (20 minutes' duration) generated various unusual electronic noises that facilitate relaxation. There were no further communications until the end of the exposure.

During the next 30 minutes, bipolar electroencephalographic activity from the temporal and occipital lobes as well as heart rate were recorded continuously by a P79 Model Grass EEG. The exposure procedure consisted of alternating 5-minute periods of field off and field on conditions (total of 3 off and 3 on intervals). During the sham field condition, the same procedure was followed except the coaxial cable was disconnected from the function generator.

All comments by the subject were recorded on tape. Audible comments and their time (to the nearest 2 seconds) of occurrence were indicated on the EEG paper for later evaluation. At the end of the 30 minutes the subject was gently contacted by the chamber microphone and told that the experiment was finished and that the door would be opened within a few seconds. After the magnetic field device, goggles and electrodes had been removed the subject was asked to complete a Subjective Experience Questionnaire (Table 1); its items were derivatives of items from the PPI (Personal Philosophy Inventory) that were most correlated with temporal lobe signs and correlative EEG signatures (11). Before the subject left the experimental area, he/she was asked to rate the experience along a 5-point scale (-2 to +2).

In light of the tendency for some subjects in a similar study to report vivid or unusual dreams during the two nights that followed the exposure, each subject was asked to record any anomalous experiences that might occur during the following days. About one month after the study was completed, all subjects that could be contacted (about half the number) were asked if they recalled their experiences within the chamber. This procedure was implemented in order to determine if any potential adverse changes had occurred.

Transcripts of each subject's spontaneous comments during the 30 minutes were obtained from the tapes. Statements emitted when the field was either on or off were differentiated. In a single sitting, the first experimenter completed the questionnaire for the comments that were emitted for the field on and off (or the equivalent time for the sham field) conditions separately. To facilitate presentation of analyses the items were collapsed into clusters (indicated in Table 1) labeled as vestibular, depersonalization, imagination, proximal modality and affect. In addition, all words (except articles and prepositions) that were emitted during the field on and field off (or equivalent periods for the sham field group) conditions were entered separately into the computerized Whissell Emotions Dictionary (29) in order to obtain activation (arousal) and evaluation (pleasantness) scores for each word. The mean of these scores for the field on conditions (combined) and off conditions (combined) were determined.

The following verbal measures were obtained: numbers of words spoken per 5-min interval, mean activation and evaluation scores for words emitted during the field off and on conditions, mean transcript rating (field off, field on and combined) and self rating for the five clusters (vestibular effects, depersonalization, etc.) from the Subjective Experience Questionnaire (SEQ). From the PPI, scores (percent yes responses) for the complex partial epileptic signs cluster (n = 16 items) and the control cluster (n = 16 items) from Persinger and Makarec (9) were obtained. Each person's scores from the four: extroversion-introversion, sensing-intuition, thinking-feeling and judgmental-perceiving dimensions of the MBTI were calculated.

Total numbers of: (1) alpha rhythm seconds, (2) spikes and (3) discrete high frequency bursts for the temporal and occipital recordings and mean heart rate were obtained for each 5-min interval. An alpha rhythm second was defined as the occurrence of 8-13 Hz synchronous activity during an entire second; a spike was defined as a sharp transient that was at least more than 2 times the width of the background activity (2,20). Enhanced (but not erratic) amplitude, fast frequency activity within the temporal

TABLE 1. Items from the Subjective Experiences Questionnaire. Inclusion within the vestibular (V), depersonalization (D), imaginings (I), affect (A) and proximal modality (P) clusters are indicated. The percentage of yes responses for the population are indicated in parentheses.

1. I felt dizzy or odd (82%) V
2. I felt the presence of someone or something (37%) D
3. There were tingling sensations (56%) P
4. I saw vivid images (37%) I
5. There were pleasant vibrations moving through my body (67%) V
6. I felt as if I had left (detached from) my body (30%) D
7. I hear an inner voice call my name (0) D
8. I experienced anger (15%) A
9. I experienced sadness (7%) A
10. The experience did not come from my own mind (0) D
11. I heard a ticking sound (67%)
12. There were odd smells (7%) P
13. I experienced terror or fear (30%) A
14. There were odd tastes in my mouth (4%) P
15. I felt as if I were somewhere else (56%) D
16. I experienced thoughts from childhood (26%) I
17. The same idea kept occurring (52%) I
18. I felt as if I were spinning around (11%) V
19. There were images from a dream I've had (11%) I
20. The red light became brighter or darker (22%) I

lobes were defined as very fast beta (gamma) frequency bursts longer than 5 seconds (usually 5-20 seconds). They are not a conspicuous movement artifact but are moderately correlated with hypertonic episodes of temporalis muscle. These EEG signatures are frequent correlates of apprehension, anger or anomalous thinking (covert talking) in our clinical populations. On the other hand, high frequency bursts from the occipital leads are more brief, erratic and typical of movement or muscle artifacts.

Four stages of analyses were completed. In order to determine reliability between experimenter's rating of the transcripts of spontaneous statements emitted by the subjects during the exposure and the subjects' self-ratings of the subjective experiences determined after the exposure, correlations between the two measures were completed for each item on the questionnaire (as well as for the five clusters). Validity was inferred from the direction and strength of correlations between: (1) the EEG measures and the verbal (words and emotional activation/evaluation) ratings and questionnaire data, and (2) the questionnaire data and the temporal lobe signs and MBTI scores. To minimize the effects from potential outliers, all correlations involved non-parametric (Spearman-rho) coefficients.

Factor analyses were completed for cluster scores of the transcripts and the subject's self-ratings on the SEQ. To determine if the psychometric coherence of the 36 subjects was similar to the other groups we have tested, intercorrelations between the temporal lobe signs score and the numbers of paranormal experiences (from the PPI) and between the numbers of temporal lobe signs and the four MBTI scales were completed.

The second stage involved the overall determination of the effects of the four treatment conditions (sham, 4 Hz, 9 Hz and 16 Hz) upon the verbal measures (on/off combined), transcript and self-rating subjective experience data (including how well they enjoyed the experience), heart rate and the EEG data; the latter involved the means of the numbers of alpha rhythm seconds, spikes and fast frequency bursts for the six, 5-minute periods for the temporal and occipital lobes. Both one-way analyses of variance and nonparametric Kruskal-Wallis analyses were completed; for the former Scheffe's ($P < 0.05$) *a posteriori* tests were completed. In addition, analyses of variance and covariance for temporal lobe signs, control cluster scores and each of the four MBTI dimensions were completed to determine if they modulated any field effects.

The third level of analyses, considered essential to clear demonstration of reversible field on/off effects, involved repeated measures analyses, using MANOVA (multivariate analyses of variance). For the numbers of words, EEG and heart rate data, the design was a 3-way analysis with two levels repeated (field on/off; 1st, 2nd and 3rd block) and one not repeated (the four treatments). Because: (1) emotional word ratings and (2) transcript ratings were completed for only the combined field on and off conditions, the 3-way analyses involved two different repeated measures. These included: (1) the field on/off measures and the activation vs evaluation scores for words; and (2) vestibular effects, depersonalization and imagination for the transcript analysis (proximal modality and affect were not included because of the overall low mean scores).

Finally, in order to insure that any small, within subject effect would not be obscured, the ratios of change in each of the EEG and heart rate measures were completed. This was done by dividing the results from the three field on periods (combined) by the results for the three field off periods (combined). Group differences were then analyzed using both parametric and nonparametric procedures. To discern possible weak correlations between these ratios and the behavioral data, correlations (Spearman rho) were completed only for those subjects (n = 27) who received any one of the three magnetic field treatments. All analyses were completed with SPSSX software on a Vax 785 computer.

RESULTS

Representative Experiences

The most typical statements displayed by the subjects exposed to the sham field condition reflected references to the odd music and to the darkness of the chamber. Qualitatively, the most unusual experiences were reported by the subjects who were exposed to the 4 Hz and 9 Hz magnetic field conditions. Classes of experiences and specific examples (in parentheses) were spinning objects ("I see something mechanical turning round and round ... and there is something brushing against it"), depersonalization ("this is not real ... I keep slipping into things"; "I feel there is something in here with me"), general vestibular effects ("I am flying in the air"; "it feels like vibrations are going through my chest"), visual flying imagery ("bats are flying in the air"; "I see a bird flying"), proprioception and muscle spasms ("... tingling over my entire body"; "my

eyes are jerking from side to side"; "I felt a weird ripple go through my head"), immobilization ("I feel like I can't move"), wave motions ("it sounds like waves"), dissociated thoughts ("I feel like I am in a story and I just woke up with a bug; he died"), colors (blue-purple, yellowish-green and red-orange, in that order) and phosphenes ("I see sparkles in a cave"). Comparisons to psychedelic sensations and the theme of a cave and a deep sea tank were the most common static references. Movement forward through a space closed on all sides was the most common dynamic reference. The frequencies of occurrence of experiences for the field exposed groups (combined), as measured by the SEQ, are shown in Table 1.

Intermeasure Reliability and Validity

The Spearman rho correlations (for all coefficients, rho >0.30, $P < 0.05$; rho >0.45, $P < 0.01$; rho > 0.60, $P < 0.001$) between the transcript rating (determined from what was displayed spontaneously during the session) and self-report scores (completed by the subjects after the session) ranged between 0.45 and 0.50 for the clusters of vestibular sensations, imaginings, depersonalization, proximal modality and affect items. Correlation coefficients between the numbers of words emitted during the session and transcript and self report scores ranged between 0.50 and 0.65 for the imagination and depersonalization clusters only. Although the mean evaluative level of the words selected to describe the experiences were not significantly correlated with any of the transcript or self-report measures, the mean Whissell emotional activity value of the words was negatively correlated with imagination scores for both the transcript (-0.63) and self-report (0.44) scores. Pleasantness of the experience was correlated with the numbers of words emitted (0.50) as well as their activity (-0.40) but not their evaluative ratings; the pleasant experience score was correlated with the following clusters from both transcript and subject self-rating measures, respectively: vestibular (0.57, 0.60), imaginings (0.61, 0.24), depersonalization (0.36, 0.35), proximal modality sensations (0.60, 0.47); the affect clusters were not correlated significantly with the pleasantness score.

Scores for the numbers of temporal lobe signs were significantly correlated with the numbers of subjective paranormal experiences (0.56) but not with the control cluster (0.18). Only the sensing-intuition (S/N) and judging-perceiving (J/P) dimensions of the Myers-Briggs Type Indicator were correlated with numbers of temporal lobe signs (0.44, 0.37, respectively; i.e., the greater the intuitive and perceiving score, the higher the temporal lobe sensitivity) but not the control (0.07, -0.13) cluster. Temporal lobe signs were correlated with imagination (0.30) and depersonalization (0.40) scores from the transcript and self-reports of the SEQ. Whereas temporal lobe signs were not significantly correlated with the numbers of words emitted or their mean activity level, the extroversion-introversion dimension of the MBTI was correlated (-0.46) with the evaluative level of the words while the thinking-feeling dimension was associated (-0.38) with the activity level of the words emitted but not the numbers of words. The total numbers of words emitted was significantly correlated with their emotional activity (-0.59) but not their emotional evaluative (-0.22) levels.

Factor analyses ($n = 36$) for the vestibular and imaginings clusters from the transcript and the subjects' self reports revealed two factors after

varimax rotation; the first factor (eigen value = 2.02, 50% variance) was loaded ($r > 0.30$) only by the two (transcript, $r = 0.89$ and subject self-report, $r = 0.88$) vestibular cluster scores while the second (eigen value = 1.14, 28% variance) was loaded by the two (0.85, 0.90, respectively) imaginings cluster scores. Factor analyses for the four MBTI scales and the temporal lobe and control scales (from the PPI) also revealed two factors; the first (eigen value = 2.09; 35% variance) was loaded ($r > 0.60$) by the temporal lobe (0.77), sensing-intuition (0.68) and judging-perceiving (0.79) scales while the second factor (eigen = 1.47, 25% variance) was loaded by the control (0.66) and the MBTI extrovert-introvert (0.74) dimension.

Validity of Verbal Measures

The correlation between numbers of alpha rhythm seconds and spikes in the temporal lobes was 0.56 ($P < 0.001$); this association for the occipital lobes was 0.12 (n.s.). Temporal lobe spikes were strongly correlated with temporal lobe alpha rhythm seconds (0.63) while occipital spikes were not correlated with alpha rhythms within that region. Our measure of movement artifacts was significantly correlated only (0.36) with the numbers of fast frequency bursts in the temporal lobes. Random selection of 8 records showed that in 81% of the first 100 pairs of temporal fast frequency and occipital lobe indicators of motor activity, the latter occurred after the temporal lobe signature by about 1-5 seconds; the other cases displayed similar (indiscriminable) onset times.

Although there were no statistically significant correlations between the number of alpha rhythm seconds (mean numbers of seconds per 5 minutes for 30 minutes) and any of the transcript, self-report, temporal lobe or cognitive style measures, mean occipital alpha rhythm activity was weakly correlated (0.31) with vestibular sensations. Numbers of spikes from the temporal lobes but not the occipital lobes were correlated with vestibular (0.41) and proximal modality sensations (0.46) from the transcript measures. Numbers of temporal lobe spikes were also significantly correlated with the overall pleasantness score (how well the subjects enjoyed the experience, 0.39) and the frequency of all experiences from both self-ratings and transcript ratings of the questionnaire (0.35, 0.36).

Of the six EEG measures only the numbers of fast frequency bursts from the temporal lobes were correlated significantly with temporal lobe signs (0.44) but not the control (-0.25) clusters; except for the weak correlation between thinking-feeling and occipital alpha activity (0.30, i.e., the more "feeling" the more frequent the occurrence of alpha rhythms), none of the MBTI scores were associated with any of the EEG measures. The numbers of occipital motor artifacts were negatively correlated with proximal modality sensations (-0.40). Mean heart rate strongly correlated with numbers of temporal lobe signs (-0.65).

Individual items from the SEQ supported the general pattern. Volunteers with more temporal and occipital spikes felt more dizzy or odd (0.30, 0.50, respectively), felt pleasant sensations moving through their bodies (0.27, 0.35) and felt as if they were spinning around and around (0.32, 0.32); sensations of a presence were associated with tempoal lobe spikes (0.30) only. People with more occipital (but not temporal) alpha experienced more thoughts from childhood (0.40) while those with more temporal (but not occipital) alpha felt more detached from their bodies (0.34).

TABLE 2. Means and Standard Deviations (in parentheses) for Heart Rate (beats/min) and Numbers of Alpha Rhythm Seconds, Spikes and Fast Frequency Bursts per 5-minute Block for Temporal and Occipital Electroencephalographic Activity

MEASURE	CONTROL	4 Hz	9 Hz	16 Hz
Heart rate	76.8(4.1)	78.9(10.6)	74.4(9.7)	74.6(9.1)
Temporal Lobes				
Alpha seconds	1.0(1.1)	4.7(4.6)	6.3(7.8)	3.0(2.8)
Spikes	1.5(0.7)[a]	2.1(1.4)	2.8(1.0)	3.4(1.5)[b]
FF displays	6.0(4.2)[a]	2.3(2.5)	3.4(2.8)	1.4(0.9)[b]
Occipital Lobes				
Alpha seconds	25.2(30.6)	60.6(43.3)	40.9(29.9)	40.8(29.6)
Spikes	1.1(0.1)	1.2(1.7)	1.5(1.5)	1.9(2.1)
Motor artifacts	1.0(1.1)[a]	0.1(0.1)[b]	0.1(0.1)[b]	0.1(0.2)[b]

a vs b = $P < 0.05$

Mean Group Differences

There were no significant group differences (grand mean and SD in parentheses) in temporal lobe signs (31±21%), the control cluster responses (80±10%) or any of the four MBTI scales scores (except for Perceiving-Judging (+16.5±28.0) the other three scales averaged within the zero range). The means and standard deviations (SDs) for the heart rate, EEG and word measures are shown in Table 2. One-way analyses of variance and non-parametric Kruskall-Wallis tests (presented first and second in parentheses, respectively) indicated statistically significant group differences for the numbers of spikes in the temporal lobes [$F(3,32) = 3.91$, $P = 0.01$; chi-square = 10.79, df = 3, $P = .01$], fast frequency bursts in the temporal lobes ($F = 4.42$, $P = 0.01$; chi-square = 9.47, $P = .02$) and occipital motor artifacts ($F = 7.10$, $P < .001$; chi-square = 10.45, $P = 0.01$).

Analyses of the major verbal measures indicated significant group differences for the mean overall subjective experience score ($F = 3.43$, $P = .05$; chi-square = 10.64, $P = .01$) and the pleasantness scale for the experience ($F = 3.28$, $P < 0.05$; chi-square = 7.25, $P = 0.05$). Comparisons of the clusters of subjective experiences from the transcripts indicated that only imagining ($F = 2.83$, $P = .05$; chi-square = 9.95, $P = .02$) and depersonalization scores ($F = 3.45$, $P = .02$; chi-square = 8.75, $P = .03$) when the fields were presented showed statistically significant group differences; group differences for the vestibular sensations approached significance ($F = 2.80$, $P = .06$; chi-square = 7.25, $P = .06$); the major group differences are shown in Table 3.

There were no group differences for these sensations when the fields were off. Scheffe's *a posteriori* analyses indicated that the primary source of the difference was between the control group and the three field conditions that did not differ significantly from each other. Only the numbers of temporal lobe spikes [$F(1,31) = 6.50$, $P = .01$] and the pleasantness rating of the experience [$F(1,31) = 8.06$, $P < 0.01$] displayed a linear increase with field frequency.

TABLE 3. Means and Standard Deviations (in parentheses) for the Numbers of Words Spoken per Block, Overall Pleasantness Rating of the Experience and Only the Statistically Significant Item Clusters from the Subjective Experience Questionnaire (transcript and self ratings) for Subjects Exposed to the Sham-Field, 4 Hz, 9 Hz and 16 Hz Magnetic Field Conditions

MEASURE	CONTROL	4 Hz	9 Hz	16 Hz
Words/Block	7.5(12.9)	11.6(8.1)	12.0(12.7)	5.8(6.3)
Pleasantness	-0.4(0.5)	0.5(1.0)	0.7(1.1)	1.0(1.0)
Transcript Rating				
Total Score	0.0(0.0)	0.2(0.1)	0.2(0.2)	0.1(0.1)
Vestibular: on	0.0(0.0)	0.4(0.4)	0.5(0.5)	0.4(0.5)
off	0.0(0.0)	0.1(0.2)	0.2(0.5)	0.2(0.3)
Imaginings: on	0.0(0.0)	0.3(0.3)	0.3(0.3)	0.2(0.1)
off	0.0(0.0)	0.2(0.2)	0.2(0.2)	0.1(0.2)
Depersonal.: on	0.0(0.0)	0.2(0.2)	0.1(0.2)	0.0(0.0)
off	0.1(0.2)	0.1(0.1)	0.1(0.1)	0.0(0.0)
Self-Rating				
Vestibular	0.3(0.3)	0.5(0.3)	0.9(0.4)	0.9(0.3)

Analyses of variance of the square-root transformation of the EEG measures, with covariance for temporal lobe signs, revealed a significant increase in alpha seconds from the temporal lobes [$F(1,28) = 3.49$, $P = .03$] but not the occipital lobes ($F = 2.36$, $0.10 > P > 0.05$) for the field exposed groups relative to the sham-exposed group; covariance for responses to the control cluster did reveal this significant change. Similar statistically significant enhancement of the numbers of temporal lobe alpha seconds in the field-exposed groups were noted when the data were first covaried wtih the sensing-intuition ($F = 5.78$, $P < 0.01$), thinking-feeling ($F = 3.41$, $P < 0.05$) and judging-perceiving ($F = 3.26$, $P < 0.05$) scores. Accommodation for these dimensions did not reveal statistically significant group differences (although all values were $0.10 > P > 0.05$) for occipital lobe alpha activity. The extroversion-introversion scores did not alter any of these effects.

Covariance for temporal lobe signs or any of the three effective MBTI dimensions did not change the strength of the significant differences between groups with respect to the numbers of temporal lobe spikes; the linear increase with field frequency was still apparent. However the significant group differences for fast frequency temporal lobe activity were eliminated (all $Fs < 2.31$, $P > 0.05$) when covariance for temporal lobe signs, sensing-intuition, thinking-feeling and judging-perceiving preceded the analyses.

Multivariate Analyses of Variance

MANOVA for the numbers of words emitted during the field on/off, different blocks (pairs of field on/off presentations) as a function of the

four groups did not display any statistically significant group effect or group by block or group field on/off interactions. A significant condition by block interaction [$F(1,32) = 8.32$, $P < 0.01$] was due to the greater increase in words emitted during the first field-on condition (coincident with the change in tempo of the astral sounds tape) in the first block compared to the other two blocks; all other interactions were not significant. Emotional activity and evaluative scores for the words displayed during the field on (combined) and off (combined) conditions displayed a statistically significant field on/off [$F(1,22) = 9.27$, $P < 0.01$] effect, a group by on/off [$F(3,22) = 4.51$, $P < 0.02$] interaction and word class (activity vs evaluation) effect [$F(1,22) = 9.34$, $P < 0.01$]. The latter was due to the greater evaluative weightings relative to activity weightings of the words that were emitted; the on/off effect was due to the use of words with greater activity and evaluative scores during the field on conditions. However close examination of the results revealed that the interaction was due to the display of words with more activity and evaluative weightings during the on vs the off blocks for the sham-exposed group compared to the field-exposed groups that did not differ from each other.

MANOVA for the vestibular, depersonalization and imaginings cluster scores from the evaluation of the transcripts of spontaneous statements during the field off and on conditions demonstrated a significant group by condition (on/off) interaction [$F(3,32) = 3.27$, $P = .03$]; this was due to the general increase in all three classes of experiences during periods when the fields were on for the 4 and 9 Hz groups compared to the sham and 16 Hz groups. The significant difference between clusters [$F(2,64) = 4.85$, $P = 0.01$] reflected the stronger vestibular experiences compared to the imaginings or depersonalization scores. A condition by block interaction [$F(2,64) = 7.69$, $P = .001$] was due to the greater increase in vestibular effects compared to the imaginings and depersonalization scores during the field on periods relative to field off periods.

Because the sham-exposed group contained such low scores because of their low response rate in general, separate MANOVAs were completed for the three field groups only for the above measures. None of these measures displayed significant differences between the three groups that were exposed to the three different frequencies. However the overall, statistically significant ($P = 0.001$) increases in vestibular, depersonalization and imagining effects (in that order) during the periods of field presentation compared to the field off periods were apparent.

Field Responsiveness and Verbal/Personality Measures

The ratios of the EEG and heart measures for all three field on (or sham) intervals divided by those measures for the three field off (or sham) intervals for the four groups are shown in Table 4. Both ANOVA and Kruskal-Wallis analyses indicated significantly more occipital spikes in the field exposed groups relative to the sham-field group during the field presentations [$F(3,32) = 3.49$, $P = 0.03$; chi-square = 9.59, $P = 0.02$]. No other electrophysiological measures displayed any significant group effects. Except for: (1) increases in numbers of occipital spikes (0.40) and the sense of presence of something or someone, and (2) enhanced temporal lobe alpha

TABLE 4. Ratio of Heart Rate and Electroencephalographic Measures for the Field Presentation Periods Divided by These Measures During the Field Off Periods

MEASURE	CONTROL	4 Hz	9 Hz	16 Hz
Heart Rate	0.97(0.02)	1.00(0.02)	1.00(0.03)	0.99(0.03)
Temporal Lobes				
Alpha seconds	0.9(0.1)	1.7(1.0)	1.4(0.6)	1.7(1.2)
Spikes	1.2(0.8)	1.7(1.1)	1.4(0.6)	1.9(0.6)
FF periods	1.3(0.5)	1.2(0.5)	1.3(0.3)	1.3(0.6)
Occipital Lobes				
Alpha seconds	1.1(0.4)	1.5(1.1)	0.9(0.4)	1.5(0.8)
Spikes	0.5(0.2)[a]	1.6(1.2)[b]	1.4(0.6)	1.2(0.5)
Motor artifacts	1.5(0.3)[a]	1.0(0.1)[b]	1.0(0.2)[b]	1.1(0.1)[b]

a vs b = $P < 0.05$

seconds and the sense of spinning around (0.45), no other correlations between these ratios and the SEQ clusters displayed statistically significant values.

DISCUSSION

Technical Comments

The results of this study strongly indicate that specific types of subjective experiences can be enhanced when extremely low frequency magnetic fields of less than 1 milligauss are generated through the brain at the level of the temporal lobes. Vestibular feelings (vibrations, floating), depersonalization (feeling detached, sense of a presence) and imaginings (vivid images from childhood) were more frequent within the field exposed groups than the sham-field exposed group. Repeated measure analyses of the transcripts for the statements generated during the 3 separate 5-minute field-on intervals (combined) compared to the statements generated during the 3 separate 5-minute field-off periods (combined) demonstrated specific increases in vestibular (particularly), depersonalization and imagining reports during the field presentations. However there were no significant alterations during field presentation periods for sensations of deep affect (fear, sadness) or for proximal modalities (touch, tingling effects).

Simultaneous electroencephalographic recordings from the temporal and occipital lobes showed that subjects exposed to the magnetic fields displayed significantly more spikes from the temporal lobes but not the occipital lobes, although both measures showed a linear relationship with the magnetic field frequency. There are three major arguments that suggest that the spike effects were not artifacts of current induction within electrodes. First, the size of the effect was relatively weak; artifacts, when they occur, are usually much stronger. Secondly, the numbers of spikes

were correlated with the numbers of field-specific experiences, such as feeling dizzy or spinning and odd or pleasant sensations moving through the body; temporal lobe spikes were correlated specifically with the sense of a presence in the chamber. Third, both the pleasantness of the experience as well as the numbers of temporal lobe spikes displayed significant field-related increases; in addition the correlation between the numbers of temporal lobe spikes and the pleasant nature of the experience was positive and statistically significant. If the spike effects had been equipment-generated artifacts, then their correlation with the experiences would not have been expected.

The general pleasantness of the magnetic field-related experiences compared to the sham-field situation was indicated by the subjects' own evaluations of their experiences. These sensations were corroborated by the highly significant reduction in motor artifacts that were noted in the magnetic field groups compared to the sham field exposed group. The coupling between pleasantness and less restless body movement is a common observation; it could be considered an index of validity.

Discrepancies between what people say during an experience (and in this situation, field exposure) and what they report in response to a questionnaire after the experience are frequent encounters in clinical settings. In the present study, moderate positive correlations were noted between the transcript evaluations of statements that were made spontaneously during the experiment and the subjects' own responses on the SEQ immediately after the end of the 30-minute period. Both types of measures demonstrated field-specific effects, although the subjects' self-ratings were weaker.

We had suspected that people who displayed more signs of temporal lobe sensitivity should be more responsive to the fields. Covariance for temporal lobe sensitivity significantly reduced the field-enhanced depersonalization and imaginings effects as well as the numbers of fast frequency bursts from the temporal lobe. All three of these measures were positively correlated with temporal lobe signs. These results suggest that a temporal lobe factor may interact with the presence of weak magnetic field applications to enhanced vestibular and imagining effects.

The most consistent clinical pattern for the fast frequency temporal lobe bursts is their coincidence with depersonalization that precede or accompany enhanced temporalis muscle (over which the T3/T4 electrodes are placed) activity, followed sometimes by a sudden, discernable body movement; this could explain the significant correlation between occipital motor artifacts and the numbers of fast frequency bursts from the temporal lobes but the lack of influence of covariance for temporal lobe signs upon the significant group effects for the numbers of occipital artifacts.

Covariance for temporal lobe signs also unoccluded the significant increase in the numbers of alpha seconds within the temporal but not the occipital lobes for subjects who were exposed to the magnetic fields. Previous research, using a markedly different protocol involving repeated, alternating minute intervals when the subject's eyes were opened or closed, showed a positive, moderate correlation between temporal lobe signs and the numbers of alpha seconds from this region (10,11). Although this correlation was not statistically significant (0.21) in this study, the results suggest that the variation in alpha activity that was associated with

temporal lobe signs was sufficient to mask the field effects. That the enhanced alpha rhythm activity was a current induction artifact of the 9 Hz field is unlikely because the effect was: (1) noted for all field frequencies, and (2) not evident for occipital alpha activity.

We had also suspected that cognitive style, a factor that strongly influences how a person interprets sensory input, would be an important modulator of field-induced phenomenological experiences. People who display more intuition (than sensing), perceiving (than judging) and feeling (than thinking) display enhanced temporal lobe signs (19). The fact that the enhanced temporal lobe alpha activity in the field exposed groups was also enhanced when covariance for sensing-intuition, thinking-feeling or perception-feeling was performed strongly indicates that the temporal lobe signs and these three indices of cognitive style share the same source of (at least psychometric) variance.

It should be emphasized that all of the field-enhanced experiences were generated within a context of unusual auditory input (the Astral Sounds Tape). These sound patterns are used to enhance relaxation and to increase temporal lobe activity in a controlled and systematic pattern so that the applied magnetic fields can interact and affect the direction of the experiences. That the sounds themselves were not responsible for the results is indicated by the significant differences in the electroencephalographic and SEQ measures between the field-exposed groups and the sham-field exposed group who only listened to the sounds but received no magnetic field pulses across the temporal lobes.

The likelihood that these results are peculiar to the subjects in the study is very low; as a group they were psychometrically similar to other populations. The mean temporal lobe sensitivity and control scores were not significantly different from those reported in a sample of approximately 500 subjects (9); the internal correlation between temporal lobe signs and paranormal experiences, a particularly robust correlation that ranges between 0.50 and 0.60, was comparable. In addition, the positive correlation between occipital alpha activity and child imaginings and memories has been reported previously (10).

Some of the results in this study generate concern. The failure to demonstrate a strong frequency dependence within the subjective measures, with the possible exception of the difference between the 4 and 9 Hz groups, suggests that all magnetic field frequencies generate similar effects. Although non-specific effects are possible, their existence makes the elimination of artifacts more difficult. No doubt there was some frequency-dependence in this study, as indicated by the linear increase in the pleasantness of the experience and the numbers of (temporal lobe) spikes as a function of field frequency. However because the frequency increase was confounded by a mild increase (a factor of about two to three) in field intensity its influence cannot be eliminated at this time.

The second major problem involves the nature of the significant activity rating of the words used during the exposures. As noted in the Results section, only the sham exposed subjects showed an increase during the field on condition. Although this might be a spurious effect because of the small (n = 3) number of sham-exposed subjects who spoke in both the on and off periods, the results can be accommodated. The increase in activity weightings of words over time (the 3 separate on times combined were compared with the 3 separate off times combined) could have reflected the

increased negative experience of the situation. Because activity weightings of words were negatively correlated with pleasantness and the sham field was less pleasant than the field conditions, the enhanced ratings by the sham group would be expected.

The third major problem of this study was the absence of a double-blind protocol. Although the frequency-dependence of the pleasantness score would appear to counterindicate potential experimenter biasing, the absence of a robust field-on/field-off effect in either the EEG or subjective experiences demands that further experiments minimize the potential contamination from subtle cues. Temporal lobe sensitivity is moderately correlated with suggestibility (15,16).

General Comments

The results of this study suggest that specific experiences, commonly generated during enhanced mesiobasal temporal lobe activity, were more frequent when pulsed magnetic fields were applied across the temporal lobes. Although vestibular (spinning), depersonalization and tingling sensations were enhanced during field presentations, the intensity of the effects were relatively small. Considering the likely current induction and its diffuse distribution, the magnitude of the effect is reasonable.

Sensations that would suggest recruitment of more extensive brain regions (e.g., gustatory and olfactory effects) and more intense activation (feeling that the experience was ego-alien, i.e., "did not come from my own mind") were not reported. Other studies (25) indicate that these experiences are intensified and the recruitment of temporal lobe space is expanded when the fields are spatially rotated over a larger region. For example, 40% of the volunteers who wore a modified helmet (in which four pairs of small solenoids were embedded) and were exposed to a spatially rotating field (once every 2 seconds) with the same pulse frequency as the one used in the present study also reported enhanced taste and olfactory experiences. About 20% of this population reported that the experiences were ego-alien ("did not come from their own mind") or were remnants of a dream (30%).

The occurrence of unusual dreams or altered experiences during the two to three days that followed the treatment were reported in only about 30% of the field-exposed subjects. With the possible exception of one subject who was convinced that the fields were now responsible for his chronic history of headaches, there were no reported complaints. We have found that people who are prone to mystical experiences often report spontaneous occurrences, involving a sense of "knowing" and anomalous phosphenes of the left upper quadrant of the visual field, within about two days after these exposures. Although the symptoms suggest enhanced right temporal lobe activity within the region of Meyer's loop, the contributions of expectancy and personality factors cannot be clearly identified at this time.

Both theoretical extrapolations, laboratory experiments and clinical experience suggest that the optimal field stimulation parameters involve complex waves that simulate the burst-firing patterns of the limbic pathways. Because most signal generators do not afford these options, computer-generated signals are now required. Although the selection of these complex waves may require laborious effort, first approximations can

be estimated by the signatures obtained from deep structure recordings (30).

The present approach, which emphasizes exposing the brain to neuro-relevant magnetic field patterns, may allow greater understanding of the functional organization of the human limbic system during dynamic states as inferred through phenomenological patterns. Because the deep temporal lobe structures are involved with the intricate processes (such as memory and meaning) that define the human sense of self (1,5,8), further exploration of this procedure might reveal some of the mechanisms associated with mystical, peak and other profound experiences. Although they are brief (in the order of minutes), these phenomena have pervasive and long-term consequences upon the behavior of normal people.

There are potential clinical applications for this research. Imagery and altered electrophysiological states are often the essential preconditions that facilitate the acquisition of new, adaptive cognitive strategies. Such state-dependent learning is required because maladaptive behaviors dominate the person's normal, mundane physiological activity and impede the acquisition of competitive (although more adaptable) responses. Most frequently this condition is evoked by pharmacological treatment. Specific stimulation by applied magnetic fields may facilitate drug treatments or attenuate their requirements.

In addition, the deep temporal lobe structures perform a tonic influence upon hypothalamic functions, one of which is the release of the stress hormone ACTH (adrenocorticotrophic hormone). The direction of the control of this immunologically important and memory-affecting neuropeptide is a function of the duration of the afterdischarge activity within the hippocampal-amygdaloid complex (31). Efficacious current induction from applied complex magnetic fields within contexts of imagery and relaxation could be explored as a useful adjunct therapy in the modulation of electrical patterns within these important brain structures.

Within a broader theoretical perspective, the isolation of the critical characteristics of electromagnetic patterns that are required to evoke imagery and altered states could facilitate the understanding of phenomena that have remained in the periphery of scientific investigation (14). For example, there is correlative evidence that bereavement hallucinations are modulated by enhanced geomagnetic activity (32). Both the distribution of the dominant modalities and their nocturnal occurrence strongly imply deep temporal lobe sources. If these ACTH-evoking grief periods increase the brain's sensitivity to natural magnetic variations, then exploration with the present technique may help isolate the mechanisms of these persistent, cross-cultural phenomena.

REFERENCES

(1) Persinger, M.A.: Religious and mystical experiences as artifacts of temporal lobe function: A general hypothesis, Perceptual and Motor Skills *57*, 1225-1262, 1983.

(2) Makarec, K. and Persinger, M.A.: Temporal lobe signs: Electroencephalographic validity and enhanced scores in special populations, Perceptual and Motor Skills *60*, 831-842, 1985.

(3) Persinger, M.A.: Geophysical variables and behavior: LV. Predicting the details of visitor experiences and the personality of experients: The temporal lobe factor, Perceptual and Motor Skills *68*, 55-65, 1989.

(4) Geschwind, N.: Interictal behavioral changes in epilepsy, Epilepsia *24* (Suppl. 1), 523-530, 1983.

(5) Bear, D.M.: Temporal lobe epilepsy: A syndrome of sensory limbic hyperconnectionism, Cortex *15*, 357-384, 1979.

(6) Stevens, J.R.: Sleep is for seizures: A new interpretation of the role of phasic events in sleep and wakefulness, in *Sleep and Epilepsy*, M.B. Sherman, M.N. Shouse and P. Passouant, eds., Academic Press, New York, 249-264, 1982.

(7) Gloor, P.: Role of human limbic system in perception, memory and affect: Lessons from temporal lobe epilepsy, in *The Limbic System*, B.K. Doane and K.E. Livingston, eds., Raven, New York, 159-169, 1986.

(8) Horowitz, M.J. and Adams, J.E.: Hallucinations on brain stimulation: Evidence for revision of the Penfield hypothesis, in *Origin and Mechanisms of Hallucinations*, W. Keup, ed., Plenum, New York, 13-22, 1970.

(9) Persinger, M.A. and Makarec, K.: Temporal lobe epileptic signs and correlative behaviors displayed by normal populations, J. Gen. Psychol. *114*, 179-195, 1987.

(10) Makarec, K. and Persinger, M.A.: Electroencephalographic correlates of temporal lobe signs and imaginings, Perceptual and Motor Skills *64*, 1124-1126, 1987.

(11) Makarec, K. and Persinger, M.A.: Electroencephalographic validation of a temporal lobe signs inventory in a normal population, J. Res. Personality (in press).

(12) Neppe, V.M.: Temporal lobe symptomatology in subjective paranormal experients, J. Am. Soc. Psychical Res. *77*, 1-29, 1983.

(13) Persinger, M.A.: Temporal lobe signs and personality characteristics, Perceptual and Motor Skills *66*, 49-50, 1988.

(14) Persinger, M.A.: Psi phenomena and temporal lobe activity: The geomagnetic factor, in *Research in Parapsychology*, L.A. Henkel and R.E. Berger, eds., Scarecrow Press, Metuchen, 120-155, 1989.

(15) Persinger, M.A. and De Sano, C.F.: Temporal lobe signs: Positive correlations with imaginings and hypnosis induction profiles, Psychol. Rep. *58*, 347-350, 1986.

(16) Ross, J. and Persinger, M.A.: Positive correlations between temporal lobe signs and hypnosis induction profiles: A replication, Perceptual and Motor Skills *64*, 828-830, 1987.

(17) Sabourin, L. and Persinger, M.A.: Specific temporal-lobe signs and enhanced delayed cross-modal matching performance, Perceptual and Motor Skills *64*, 309-311, 1987.

(18) Persinger, M.A. and Valliant, P.V.: Temporal lobe signs and reports of subjective paranormal experiences in a normal population: A replication, Perceptual and Motor Skills *60*, 903-909, 1985.

(19) Huot, B., Makarec, K. and Persinger, M.A.: Temporal lobe signs and Jungian dimensions of personality, Perceptual and Motor Skills *69*, 841-842, 1989.

(20) Persinger, M.A.: Striking EEG profiles from single episodes of glossolalia and transcendental meditation, Perceptual and Motor Skills *58*, 127-133, 1984.

(21) Persinger, M.A.: Modern neuroscience and near-death experiences: Expectancies and implications. Comments on "a neurobiological model for near-death experiences", J. Near-Death Studies *7*, 233-239, 1989.

(22) Mahl, G.F., Rothenberg, A., Delgado, J.M. and Hannibal, H.: Psychological responses in the human to intracerebral electrical stimulation, Psychosom. Med. *26*, 337-368, 1964.

(23) Neppe, V.M.: Modern perspectives on epilepsy in relation to psychiatry: Classification and evaluation, Hosp. Commun. Psychiatry *39*, 263-271, 1988.

(24) DeSano, C.F. and Persinger, M.A.: Geophysical variables and behavior: XXXIX. Alterations in imaginings and suggestibility during brief magnetic field exposures, Perceptual and Motor Skills *64*, 968-970, 1987.

(25) Persinger, M.A. and Makarec, K.: Enhancement of temporal lobe specific phenomenological experiences by spatially rotating, 4 or 16 Hz pulsed magnetic fields (in preparation).

(26) Persinger, M.A. and Nolan, M.: Partial amnesia for a narrative following application of theta frequency electromagnetic fields?, J. Bioelectricity *4*, 481-494, 1985.

(27) Michaud, L.Y. and Persinger, M.A.: Geophysical variables and behavior: XXV. Alterations in memory for a narrative following application of theta frequency electromagnetic fields, Perceptual and Motor Skills *60*, 416-418, 1985.

(28) Berger,R.E.: The Myers-Briggs Type Indicator (MBTI) and Psi research, Res. Parapsychol. (in press), 1989.

(29) Whissell, C.: The dictionary of affect in language, in *Emotion: Theory Research and Experience,* R. Plutchik and H. Kellerman, eds., Academic Press, New York, in press.

(30) Isokawa-Akesson, M., Wilson, C.L. and Babb, T.L.: Structurally stable burst and synchronous firing in human amygdala neurons: Auto- and cross-correlation analysis in temporal lobe epilepsy, Epilepsy Res. *1*, 17-34, 1987.

(31) Gallagher, B.B., Flanigan, H.F., King, D.W., Smith, J.R., Murro, A.M. and Littleson, W.: ACTH secretion and human temporal lobe epilepsy, in *Fundamental Mechanisms of Human Brain Function*, J. Engels, G.A. Ojemann, H.O. Luders and P.D. Williamson, eds., Raven, New York, 201-208, 1987.

(32) Persinger, M.A.: Increased geomagnetic activity and the occurrence of bereavement hallucinations: Evidence for melatonin-mediated microseizuring in the temporal lobe?, Neurosci. Lett. *88*, 271-274, 1988.